State of Illinois
DEPARTMENT OF PUBLIC WORKS AND BUILDINGS
Division of Highways
Bureau of Research and Development

ROUTE U.S. 66 CONDITION SURVEY

Final Summary Report for Illinois Project IHR-6

by

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A Research Study

by

ILLINOIS DIVISION OF HIGHWAYS
in cooperation with
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

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ABSTRACT

The Route U.S. 66 Condition Survey was undertaken by the Illinois Division of Highways in 1949 in response to a need to document the association believed by most engineers to exist between axle loads and pavement damage. It was a load-condition type of study in which repetitive surveys were made to obtain a condition history of the pavements under observation. Routine axle weighings and classified vehicle counts that had been made for many years prior to the study and which continued during the study were expected to furnish the required load history information. During the course of the survey, on which field work was concluded in 1967, it became recognized in Illinois and elsewhere that such surveys probably would never develop the sought-after load-condition relationship. This remained for the AASHO Road Test to accomplish with controlled axle loadings. The Route U.S. 66 Condition Survey did, however, furnish a large quantity of essential data that was used in modifying the formulas devised to depict the load-condition relationships developed at the AASHO Road Test to produce pavement design equations that represented actual service conditions in Illinois. The survey also furnished a considerable amount of qualitative information on pavement and shoulder designs and materials in use in Illinois.

This final summary report for the project briefly describes the locale of the study, the pavements and other features under observation, and the survey techniques employed. Results of the project, primarily of a qualitative nature, are presented. A retrospective critique of the survey that is included will be of value to others giving consideration to undertaking condition surveys.

SUMMARY

The Route U.S. 66 Condition Survey was undertaken by the Illinois Division of Highways in 1949 in an effort to document the association believed to exist between axle loads and pavement damage. This information was badly needed by legislators who were being strongly pressured to raise load limitations at a time when many existing pavements were suffering from extensive damage incurred during the heavy hauling of World War II years.

The Illinois survey was a load-condition type of study in which repetitive surveys were made to obtain a condition history of the pavements under observation. Routine axle weighings and classified vehicle counts that had been made for many years prior to the study and which continued during the study were expected to furnish the required load history information. All observable conditions and defects, whether or not they appeared to be load-associated, were recorded in the field study.

In the field work, observed details were carefully located and plotted to scale on sketch sheets prepared specifically for the purpose. Appropriate symbols were established for recording the extent and severity of the various defects observed. From one to several two-man parties conducted the field work.

Route U.S. 66 in Illinois is a major commercial artery with a high percentage of heavy long-haul vehicles traveling its total length between Chicago and the Mississippi River where it enters Missouri at St. Louis. Initially, only the 200-mile portion between Chicago and Springfield was included in the survey. As the survey progressed, almost all of the pavement between Chicago and St. Louis was included in the study. In 1949, the facility was essentially a two-lane highway. By 1964, it was totally a four-lane divided highway.

A variety of rigid pavement design features that followed National trends through the years beginning in 1926 were included in the observations. Bituminous concrete resurfacings became a prominent feature during the latter years of the survey. Granular subbases to combat mud-pumping were a part of the rigid pavement construction beginning in the early 1940's. Paved shoulders adopted during the latter stages of the survey were studied in an auxiliary investigation.

The Route U.S. 66 Condition Survey, while not accomplishing its original objective, proved to be a very timely and appropriate source of a large quantity of essential data that was used in modifying the formulas devised to depict the load-condition relationships developed at the AASHO Road Test to produce design equations that represented actual service conditions in Illinois. The survey also furnished a considerable amount of qualitative information regarding good and bad features of pavement and shoulder designs and materials in Illinois.

In addition to treating the preceding in summary fashion, the final summary report presents a retrospective critique of the survey that should be useful to others planning to conduct condition surveys. The need for advance planning that includes a careful selection of data to be gathered, a thorough understanding of the analysis to be performed, and the ascertainment that the two are compatible and related to the attainment of the research objective, is pointed out. The importance of having reasonable assurance that people qualified to perform what may be difficult interpretive work will be available for the survey is also stressed.

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INTRODUCTION

In the years immediately following the close of World War II, strong pressures were being exerted on state governing bodies to raise vehicle load limits above those that had been established prior to the war but which were often ignored during the war crisis. These pressures were of great concern to highway agencies already deeply involved with the problems of maintaining substantial mileages of old pavement damaged during the war years and obviously incapable of adequate service even under existing load limitations.

In an effort to document the association that they were convinced existed between heavy vehicle loads and pavement damage, the Illinois Division of Highways, and many other state highway agencies, undertook at this time various pavement condition surveys that hopefully would show the true load-damage relationship. The state studies received strong support from the Federal Bureau of Public Roads.

It has been generally recognized that certain pavements deteriorate more rapidly than others, and that deteriorated pavements are often exposed to a greater-than-average frequency of heavy loads. Load-condition studies have all been undertaken with the basic assumption that a load-damage relationship exists, and have had the common objective of establishing this relationship.

While all load-condition studies have had the same objective, the methods of approach have varied considerably. The first load-condition studies were relatively simple attempts to establish a relationship between truck counts, pavement defects, and maintenance costs. Almost invariably, whatever relationships might have existed were obscured by extraneous variables. Later attempts involved periodic weighings of vehicles and repetitive surveys of pavement condition designed to detect changing conditions that might assist in developing the sought-after correlation. Like the earlier attempts, none were truly successful.

The Route U.S. 66 Condition Survey with which this report is concerned was a final attempt by the Illinois Division of Highways to establish a correlation between vehicle loadings and pavement damage by the load-condition survey process. A special effort was made to overcome all of the deficiencies of previous surveys.

A major commercial artery with a high percentage of heavy long-haul vehicles traveling the entire length under observation was selected for study. It was believed that this control over the traffic variable would help to overcome previous problems of load analysis where the complexities of this variable defied resolution.

About 200 miles of pavement, including what was believed to be a reasonable range of design and soil support characteristics, were placed under observation. This length of pavement was much greater than had ever been placed under observation in load-condition surveys previously, and it was hoped that the magnitude was now sufficient to level the extraneous variables that seemed always to interfere in previous analyses.

All pavement defects were recorded regardless of whether or not they appeared to be load-related. This was done primarily with the thought that a complete recording of defects would aid in isolating those that were truly related to traffic loadings. However, it was recognized also that the recorded information would have broader use in identifying good and bad features of structural design, material usage, and construction processes.

The original objective of developing positive relationships between pavement behavior and applied loadings, solely on the basis of project data, was never achieved. Difficulties of the type experienced in this and similar surveys in the matter of relating pavement damage to traffic loadings led to the series of controlled traffic pavement studies that culminated in the AASHO Road Test conducted in Illinois during 1958-1960. Although considerably more expensive, the controlled traffic studies proved to be the only means for developing the long-sought correlations between pavement damage and applied loadings.

While a great quantity of data on pavement defects was obtained during the course of the Route U.S. Condition Survey, and much of the data was summarized for analysis, the analytical work almost invariably ended in a series of charts and graphs that showed no particularly significant relationships between the variables under consideration. If such relationships truly existed, they were obscured by the interaction of the almost innumerable variables that can reasonably be expected to influence pavement behavior.

The Route U.S. 66 Condition Survey, nevertheless, has produced a large quantity of information that has received practical application through the years. In some instances, this information has come from the regular survey data accumulation; in other instances, it has come from special studies of specific conditions or studies of experimental construction added to the project.

At various times during the study when significant advances appeared to have been achieved, formal reports were prepared. Often however, when questions have arisen with regard to particular construction materials and structural designs, the records of the Route U.S. Condition Survey have been searched and used without benefit of formal papers.

The availability of the pavement condition data gathered through the years on the Route U.S. 66 Condition Survey proved to be a most fortuitous circumstance when the development of a pavement design system based on application of the AASHO Road Test findings was undertaken by Illinois. The records of this survey were a primary source of information that was used in modifying the Road Test formulas for predicting pavement performance to be expected under actual service conditions in Illinois.

The Route U.S. 66 Condition Survey (Illinois project identification IHR-6) has been conducted in cooperation with the Federal Highway Administration since 1959. From its beginning in 1949 until 1959, it was supported totally with State funding.

The purposes of this report are to describe briefly the principal procedures that were used during the course of the survey, to summarize the major results that were achieved, and to provide a retrospective discussion of some procedure situations encountered during the course of this survey that might well be considered when planning future condition surveys.

LOCALE

Route U.S. 66 originates in Chicago and traverses Illinois in a generally southwest direction to the Mississippi River at St. Louis, Missouri (Figure 1). A number of cities are served between the two major metropolitan areas of Chicago and St. Louis, but, overall, the area through which Route U.S. 66 passes is predominantly rural. Rainfall and soil conditions support intensive farming. Initially, the survey was to be confined to the portion lying between Chicago and Springfield, approximating 200 miles. Beginning in 1951, sections south of Springfield were added to the program.

In 1949, Route U.S. 66 between Chicago and Springfield was essentially a two-lane highway as shown in Figure 2. Exceptions to this were an undivided four-lane

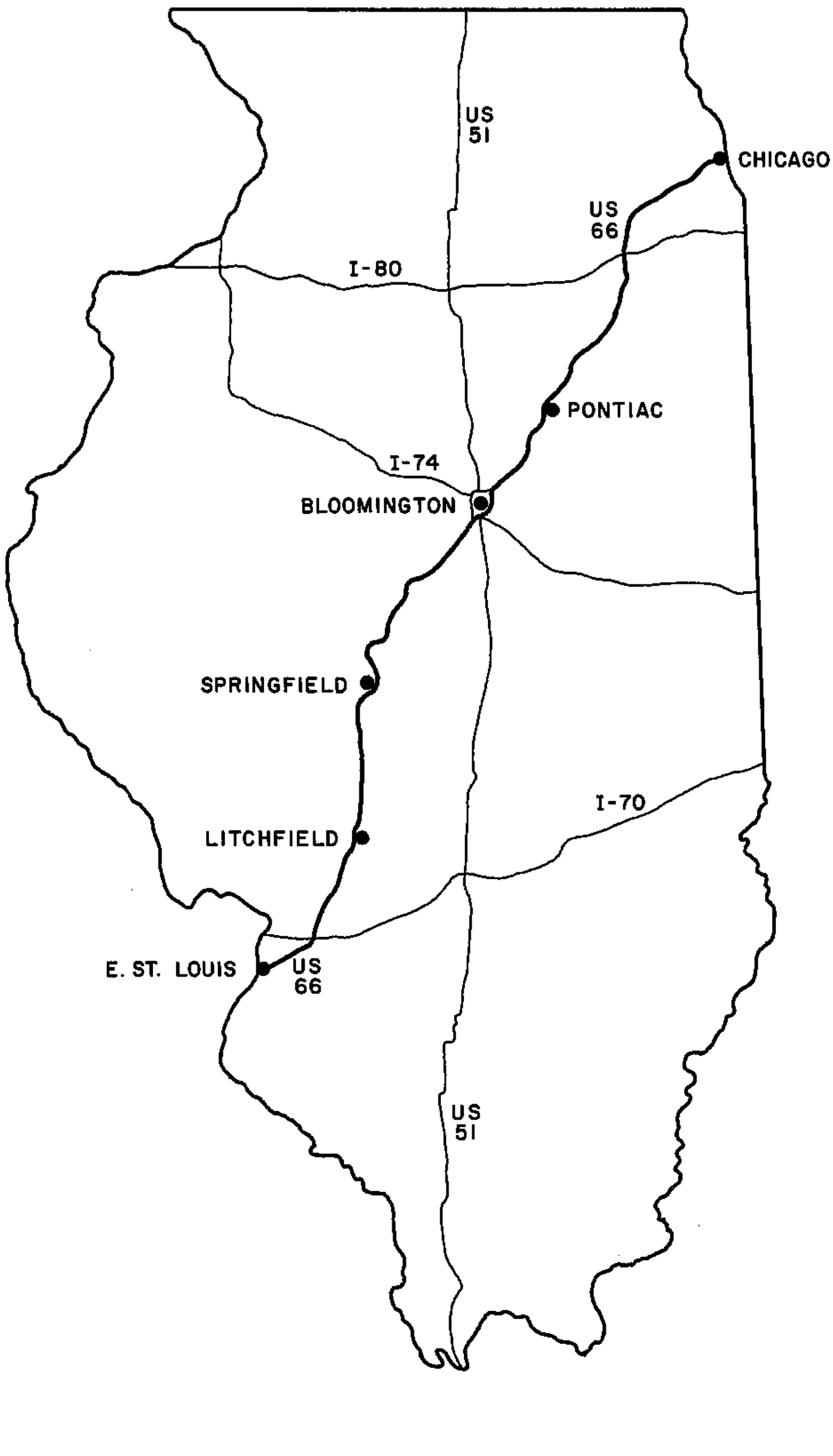

Figure 1. Location of Route U.S. 66 in Illinois

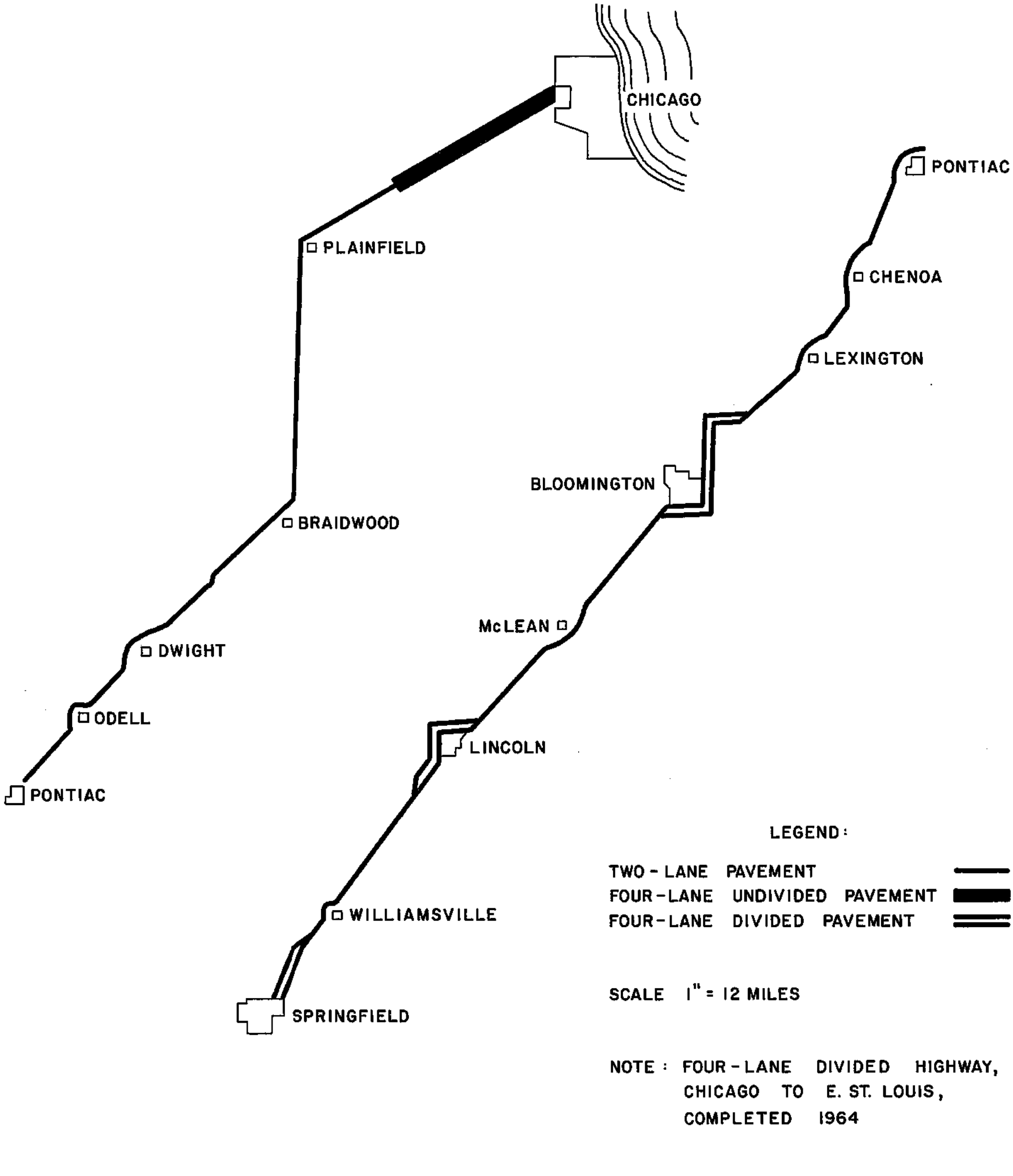

Figure 2. Route U.S. 66 at start of survey in 1949
(Original survey Chicago to Springfield only)

pavement extending the first several miles out of Chicago, four-lane divided facilities bypassing Bloomington and Lincoln, and a four-lane divided highway approaching Springfield. Most, but not all, of the smaller villages along the route had been bypassed.

An extensive program of upgrading Route U.S. 66 in Illinois to a multilane divided highway facility began in 1953. By 1964, the multilane facility was complete. During the first years, multilaning was accomplished primarily by placing a second pavement adjacent to the existing facility. When the Interstate Highway System came into being, the alignment of Interstate 55 was selected to follow the general location of Route U.S. 66, and a substantial mileage of totally new construction meeting Interstate standards was added to serve the through traffic formerly carried by nearby portions of Route U.S. 66. This work began about 1961, and a number of sections completed before termination of the survey field work in 1967 were added to the study both north and south of Springfield.

PHYSIOGRAPHY AND SOILS

Route U.S. 66 between Chicago and St. Louis principally traverses five recognized and named physiographic divisions. In Illinois, physiographic divisions have been established mainly on considerations of glacial geology. While no major differences occur between divisions in surface configurations, those that are present are easily identifiable. Soil characteristics often differ significantly between divisions. The physiographic divisions of Illinois, with the location of Route U.S. 66, are outlined in Figure 3. Descriptions of the principal divisions traversed by Route U.S. 66 follow. This information has been extracted from the report "Soil Deposits of Illinois," prepared under the Illinois Cooperative Highway Research Program at the University of Illinois and published by the University as Civil Engineering Studies Soil Mechanics Series No. 3.

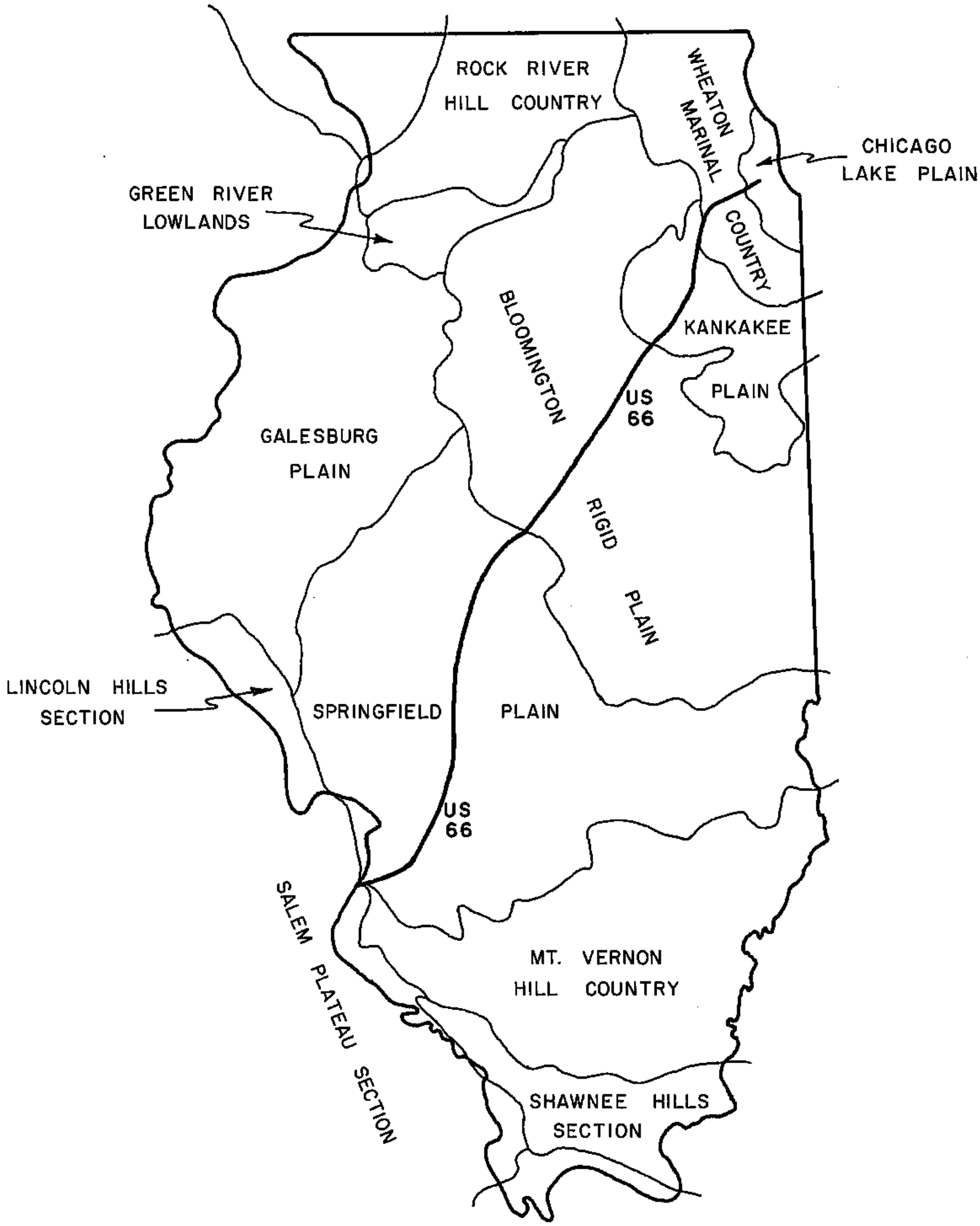

Figure 3. Physiographic Divisions traversed
by Route U.S. 66 in Illinois

The Chicago Lake Plain is characterized by a generally flat surface that slopes gently toward Lake Michigan. AASHO soil classifications for this division vary from A-2-4 to A-3 near the lake with A-2-4 to A-4 and A-6 to A-7-6 soils lying further west.

The soils near Lake Michigan were developed from sandy loams and sands that were deposited originally by water and partially reworked by the wind. For all horizons the AASHO standard maximum dry densities range between 105 and 125 pcf, with optimum moisture contents ranging between 10 and 20 percent and clay (0.002 mm) contents ranging between 3 and 30 percent. Both surface and internal drainage range from poor to very good.

Soils further west of Lake Michigan were developed from moderately fine-textured glacial outwash. Silt loam and silty clay loams are predominant, with standard densities in all horizons ranging between 90 and 125 pcf. Optimum moisture contents range between 10 and 24 percent in the A horizon and slightly less in the others. Clay contents range between 10 and 40 percent. Both surface and internal drainage range between moderate and poor.

The Wheaton Morainal Country surrounds the Chicago Lake Plain, extending into Wisconsin on the north and Indiana on the east, and is characterized by a rolling morainal topography. The south-central portion of the division, which Route U.S. 66 traverses, is predominantly a fine-textured till. AASHO soil classifications for the A horizon are typically A-7-5 or A-7-6, the B horizon is normally A-7-6, and the C horizon is typically A-7-6 with an occasional A-6. For all horizons the maximum AASHO standard dry densities range between 90 and 115 pcf. Optimum moisture contents range between 15 and 25 percent, and clay contents range between 25 and 60 percent. Surface and internal drainage vary from moderate to very poor.

The Kankakee Lake Plain follows the Kankakee River from its entry into Illinois at the Indiana line to its junction with the DesPlaines River to form the Illinois River. It is a flat area in which the water table is consistently high. The soils which Route U.S. 66 traverses in this division vary from A-3 sand to A-7-6 clay. AASHO standard densities and moisture contents vary widely. Both surface and internal drainage are generally poor.

The Bloomington Ridged Plain lies almost entirely in central Illinois, with its boundary lines extending from the Wheaton Morainal Country on the north into Indiana on the southeast. The surface is characterized by low broad morainic ridges alternating with intervening wide stretches of relatively flat or gently undulating till plains.

Much of the soil in the corridor through which Route U.S. 66 was constructed has developed from silty loessial material. The A horizon is generally a fairly plastic soil classifying A-7-5, A-7-6, or A-6. The B horizon is mostly A-7-6 of fairly high to moderate plasticity. The C horizon is rather variable. For all horizons, the maximum dry densities range between 90 and 110 pcf; optimum moistures range between 10 and 25 percent; and the clay contents range between 10 and 40 percent. Surface and internal drainage vary between poor and moderately good.

The Springfield Plain crosses south-central Illinois south of the Bloomington Ridged Plain from Indiana on the east to the Mississippi River on the west. The northernmost point in the division is near Peoria, with the western boundary extending along the Illinois River to the Mississippi River, then south to just south of East St. Louis. The boundary then extends east-northeast to the Indiana line. The surface is generally flat to very gently rolling with an occasional well-developed morainal ridge. Drainage systems, while well-developed, are generally not deeply entrenched.

A cover of loess two feet or more in thickness occurs over most of the corridor of Route U.S. 66. The A horizon is very silty and generally classifies as an A-4(8), the B horizon lies in the A-7-6 (15 to 20) classification, and the C horizon is typically an A-6 or A-7-6, but may vary to A-4, depending upon the character of the underlying Illinoisan drift and its depth. For all horizons, AASHO standard maximum densities range between 90 and 115 pcf; optimum moistures range between 10 and 25 percent; and clay contents range between 15 and 50 percent. Surface and internal drainage range from fair to very poor.

ROADWAY AND PAVEMENT FEATURES

It has been mentioned previously that Route U.S. 66 was essentially rural in character at the time the Route U.S. 66 condition survey was undertaken in 1949. Although numerous alignment changes were made during the period of the survey, this characteristic was retained throughout the survey life. The roadway cross sections, and the vertical and horizontal alignments, in 1949 were representative of those in use in the 1920's, 1930's, and early 1940's. Right-of-way widths ranged upward from 80 feet or somewhat less. Balancing of cut and fill in the typically flat to very gently rolling area traversed resulted in shallow cuts and low embankments in most of the early construction. The turf shoulders employed throughout the entire length ranged from a few feet to ten feet in width. Pavement widths in 1949 ranged from 18 to 24 feet. Except for a small mileage of bituminous concrete resurfacing, the pavements were of portland cement concrete.

The presence of subbase in 1949 was limited almost entirely to the construction that took place during the later war years. With few exceptions, a trenched subbase of unstabilized granular material was used. Otherwise, pavements were placed on natural soil subgrades.

During the reconstruction and upgrading of Route U.S. 66 that began in the 1950's and which was continuing at the time the last field survey was made in 1967, cross sections and alignments that are still considered reasonably modern were employed. New pavements were constructed of portland cement concrete and placed on trenched granular subbase. Where older pavements could be retained in the new alignments, they were resurfaced with bituminous concrete. At the time the survey was terminated, a general upgrading of the shoulders was taking place, both through the use of unstabilized granular materials and full paving treatments.

Like most other state highway departments constructing portland cement concrete pavements, the Illinois Division of Highways through the years has made numerous changes in its pavement design features in an effort to improve pavement service. The designs that have been used by Illinois during any single period usually have coincided with Nationwide trends. The Route U.S. 66 Condition Survey, in covering pavements constructed over a period of about 40 years, included a numerous array of design features. Except for a few isolated instances that are not of particular consequence, the designs can be separated to represent fairly definite construction periods.

The oldest of the pavements included in the survey were representative of those commonly constructed in Illinois during the period of 1926 to about 1932. A thickened-edge cross section was used, along with steel edge-bar reinforcement at the outside edges of the pavement. Four-inch open expansion joints were installed at 800 to 1000-ft intervals. No load transfer devices were provided at the expansion joints, but the interior of the pavement was thickened to the 9-inch edge thickness to provide added strength. A V-type steel longitudinal center joint was used, with deformed steel tie bars. Details of this and the other principal design systems included in the study are shown in Table 1.

TABLE 1

PRINCIPAL DESIGN FEATURES OF PAVEMENTS OF ROUTE U.S. 66[1/]

Construction Year	Number of Construction Sections	Cross Section (in.) (ft)	Reinforcement	Transverse Joint Type and Spacing: Expansion	Transverse Joint Type and Spacing: Contraction	Transfer Devices	Center Joint	Subbase
1926-32	5	9-9-7-9-9 x 20 9-7-9 x 20	7/8-in. dia. edge bars	4" open; 800-1000 ft	none	none	metal; tie bars	none
1933-37	9	9-9-7-9-9 x 22	none	metal air chamber (3/4 in.); 90 ft	metal plate; 30 ft	dowels and other types	metal; tie bars	none
1938-41	13	9-9-7-9-9 x 22 10-10-8-10-10 x 22	welded wire fabric; 54 lb/100 sf	bitum. fiber filled (3/4 in.); 50 ft	none	dowels and other types	metal; tie bars	none
1942-43	8	10-in. uniform x 24	none	bitum. fiber filled (1 in.); 120 ft	impressed; 20 ft	none	metal; tie bars	trenched granular
1944-46	15	10-in. uniform x 24	welded wire fabric; 78 lb/100 sf	bitum. fiber filled (1 in.); 100 ft	none	dowels	metal; tie bars	trenched granular
1947-	129	10-in. uniform x 24	welded wire fabric; 78 lb/100 sf	none	metal plate or sawed; 100 ft	dowels	metal or sawed; tie bars	trenched granular

1/ Occasional exceptions to the basic designs that were present are not included in the tabulation.

Pavements constructed in Illinois during the period 1933 to 1937 were characterized by a closer spacing of transverse joints than had been used previously except in isolated instances. Edge-bars were no longer used. Metal air-chamber joints were spaced at 90-ft intervals with intermediate full-depth metal contraction joints at 30-ft intervals. The joints were rather elaborately constructed to move with the pavements without allowing the entrance of water and incompressibles. Various kinds of load transfer devices were used in conjunction with the joints. No distributed steel reinforcement was used.

During the period 1938 to 1941, Illinois pavements for the first time featured the use of distributed welded wire reinforcement. Transverse expansion joints were used, spaced at 50-ft intervals. Expansion joint openings were filled with premolded bituminous fiber. The use of load-transfer devices that began in 1933 was retained.

During the early war years of 1942-43, when steel was in short supply, all steel was removed from Illinois pavement except for the tie bars across the longitudinal joints, and the transverse joint spacing shortened to 20 feet to aid in crack control. In this new design, expansion joints were placed at 120-ft intervals and intermediate contraction joints at 20-ft intervals. The use of granular subbase to control mud-pumping began in Illinois while this design was in use and continued until the late 1960's when bituminous and cement stabilization was added to upgrade subbase performance.

Beginning in 1944 when steel again became available and continuing through the remaining years of construction covered in the Route U.S. 66 Condition Survey, distributed welded wire reinforcement was used in Illinois pavements in conjunction with transverse joints spaced at 100-ft intervals. During the period 1944-1946, expansion joints were used at the 100-ft spacing; thereafter, contraction joints were used at this spacing.

In common with other states, Illinois gradually increased its pavement thicknesses through the years and followed the trend toward greater lane widths.

Resurfacings placed and observed during the period of the survey have been of fine dense-graded bituminous concrete (subclass I-11), and, with few exceptions, have included equal thicknesses of binder and surface courses totaling three inches for both courses.

During the period of construction of the older pavements of the Route U.S. 66 Condition Survey, design changes, in addition to those made to increase the load-carrying capacity of the pavements, were directed principally at the avoidance of blowups. By the mid-1940's, when mud-pumping had become the overriding problem, one effort to reduce it led to the elimination of the expansion joints that were always a part of designs aimed at avoiding blowups. The principal design change to control pumping was, however, the addition of granular subbases.

MATERIALS

Specifications governing the materials incorporated in the pavements and resurfacings of the Route U.S. 66 Condition Survey, and that governed the mixture compositions and construction processes, like the pavement designs mentioned previously, did not remain static during the 40 years of construction activity covered by the survey. New test controls were added on occasion, the mortar-voids theory of concrete mixture design and weight-proportioning were introduced, refinements were made in paving equipment to produce better uniformity, and other changes were made to improve construction. Undoubtedly, most of the changes resulted in an overall improvement in the product. Unfortunately, differences in age, in load environment, and in the many other variables that so often mask the influences of individual variables affecting pavements in service prevented the development of any quantifiable correlations in this regard.

The most observable product improvement was that which occurred with the introduction of air entrainment in concrete mixtures in the late 1940's. The effect of air entrainment in the control of salt scale was very obvious, especially when comparing pavements constructed after the use of chlorides in the control of salt scale became popular. It was observed on the U. S. 66 Condition Survey, as it has been observed elsewhere, that older pavements constructed without air entrainment and which served for many years before the use of the deicing agents offered a fair degree of resistance to scaling.

Portland cements for the pavements covered in the Route U. S. 66 Condition Survey were furnished from 8 plant sources, fine aggregates from 32 plant sources, and coarse aggregates from 20 sources. All aggregates were furnished by commercial producers. While plant locations and general geologic formations and deposits from which the aggregates were obtained were easily identified, no records were available on the locations within pits or ledges within quarries from which specific materials were obtained.

Except for some differences in the resistance of the concretes to deterioration of the type associated with D-cracking, usually believed to be traceable to certain characteristics of the coarse aggregates, no important correlations between pavement behavior and construction materials were noted. The study did not go beyond recognition of the existence of the observed relationships, and the reasons for the differences in behavior were not identified.

SURVEY PROCEDURE

The Route U. S. 66 Condition Survey was conducted on foot by two-man parties in which one member, serving both as an observer and recorder, walked along the outside shoulder and the other member, serving as an observer, walked along the inside shoulder. All observable items appearing to have some bearing on performance were recorded on special printed sketch sheets prepared for the purpose. A sample completed sketch sheet is shown in Figure 4.

Distance measuring wheels or 100-ft tapes (chains) were used to assist in locating features to be recorded on the field sketch sheets. Stationing was kept as close as possible to the original location survey stationing. Station numbers that had been inset in the pavement and resurfacings at 250-ft intervals during construction aided in maintaining the original stationing.

The Route U.S. 66 Condition Survey was a repetitive-type of study in which resurveys were conducted periodically to record time-dependent behavioral changes. It was believed that the recording of the advances of damage and deterioration would assist in the exploration and assignment of causes. Although field survey work was done almost every year during the period of study, no survey of all pavements was ever made in any one year. Usually, pavements of the individual construction sections were surveyed at two- to three-year intervals. The level of effort varied considerably from year to year depending on the availability of people.

Survey sketch sheets used in the field were a good grade of fairly water-resistant tracing paper. Reproductions of completed sheets were made following each survey by the ozalid process, and the tracing-paper sheets reused for successive surveys.

Transverse joints were imprinted on the field sketch sheets for each of the joint spacings commonly used in Illinois. Sheets were also printed for the no-joint condition. During the surveys, all of the commonly recognized defects were recorded, such as cracks, faults, spalls, corner breaks, scale, D-cracks, ravel and pumping. A manual of instructions was developed for field-party usage in which the various defects known to occur were described and severity classifications established. Photographs of typical defects were also provided. Definitions, severity classifications, and method of recording followed insofar as possible previous usage by the

STATE OF ILLINOIS
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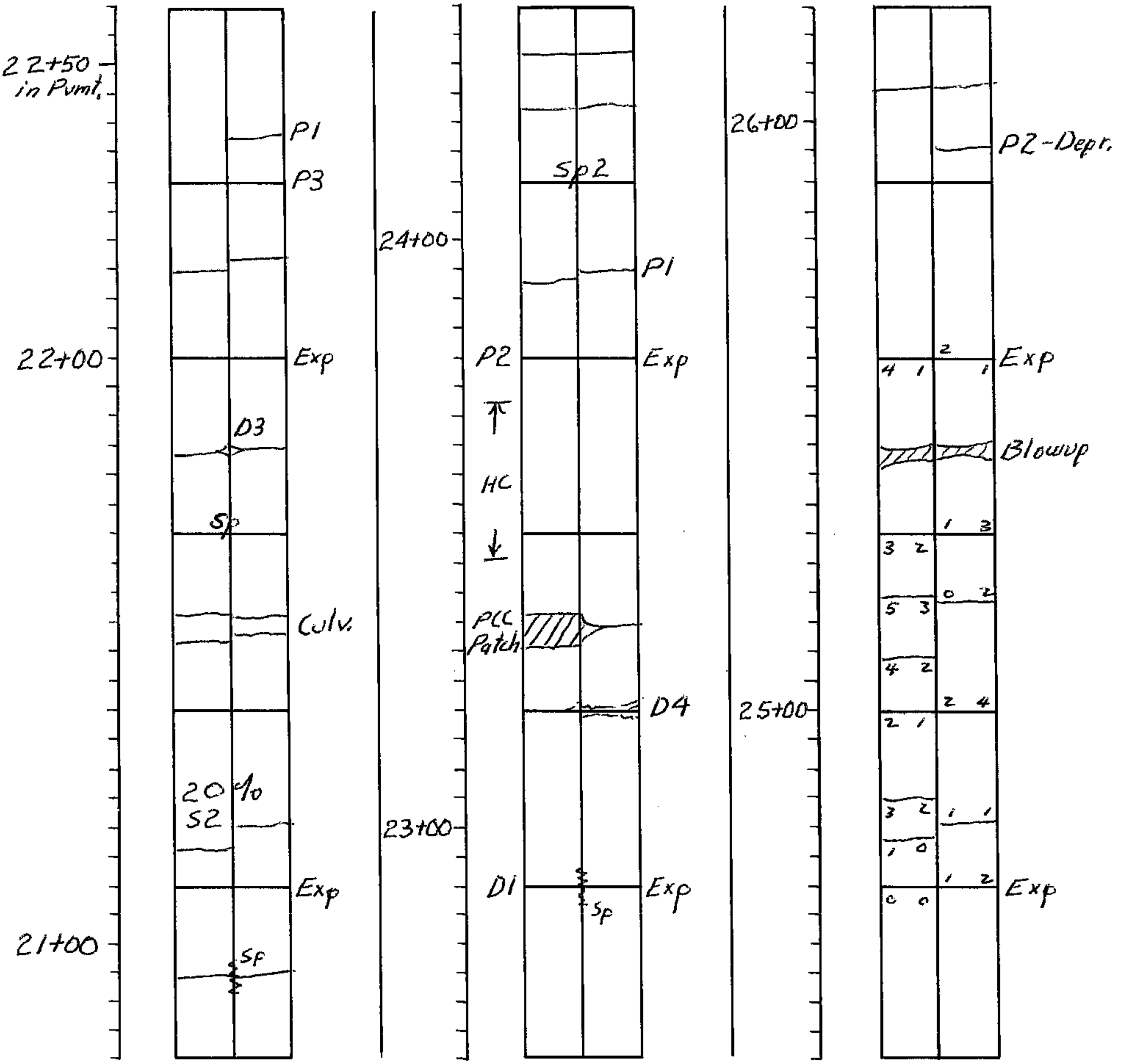
BUREAU OF RESEARCH AND PLANNING

CONDITION SURVEY FIELD SKETCH SHEET

MARKED ROUTE *U.S. 66*
SBI,FA,SA RT. *SBI 4*
SECTION *5*
COUNTY *Will*
DISTRICT NO. *3*



REMARKS *Shoulders 1" to 2" low*
Seal broken at joints and cracks.
Light spall at most joints and cracks.
Joints and cracks partially open, and
generally packed with debris.

Clear - 50°

NAME: *JES*
DATE: *10-11-49*

Figure 4. Sample field sketch sheet

Portland Cement Association and others that had engaged in pavement condition surveys and reported their work in Highway Research Board literature. Following is a discussion of the principal deficiencies observed, and of the severity classifications that were used to record the degree of distress.

Portland Cement Concrete Pavement Deficiencies

Transverse Crack (also longitudinal or diagonal, dependent on angular relationship to pavement centerline) -

Mapping symbol.--single line on sketch sheet, except under condition of very close spacing where area only was shown and identified as concentrated cracking by the letters "CC"

D-Cracks - fine, closely-spaced cracks usually paralleling a joint or major crack and usually curving around slab corners; a gray deposit often visible at crack surface

Mapping symbol.--"D," followed by numeral identifying severity rating

Severity rating.--

D1 - cracking without raveling

D2 - cracking, with raveling extending up to 6 inches from joint, crack, or pavement edge

D3 - cracking, with raveling extending 6 to 12 inches from joint, crack, or pavement edge

D4 - cracking, with raveling extending over 12 inches from joint, crack, or pavement edge

Load Corner Break - a break in the pavement at the junction of a transverse joint or crack with a longitudinal joint or pavement edge, characterized by the formation of a diagonal crack a minimum of about two feet from the corner

<u>Hair-Checking</u> - short, often diagonal, cracks that form in the plastic concrete and usually occur in interior slab area; sometimes called "plastic shrinkage" cracks

<u>Mapping symbol</u>.--the letters "HC"

<u>Blowup</u> - pressure buckling or shattering at a transverse joint or crack

<u>Mapping symbol</u>.--"Blowup"

<u>Depressed Slabs</u> - slabs depressed from constructed profile under traffic loadings

<u>Mapping symbol</u>.--"Depr."

<u>Raveling</u> - disintegration of concrete characterized by the separation of individual aggregate particles from the matrix

<u>Mapping symbol</u>.--normally associated with D-cracking and not identified separately; symbol "R" used if occurring separately

<u>Spall</u> - chipping of the pavement at joints, cracks and pavement edges

<u>Mapping symbol</u>.--spalled area sketched, or symbol "Sp" used

<u>Severity rating</u>.--

I - width 5/8 inch or less at pavement surface

II - width 5/8 to 1 3/4 inches at pavement surface

III - width 1 3/4 to 3 inches at pavement surface

IV - width over 3 inches at pavement surface

<u>Scale</u> - disintegration and loss of wearing surface

<u>Mapping symbol</u>.--the letter "S," followed by a number identifying the severity rating

<u>Severity rating</u>.--

S1 - peeling of surface mortar only

S2 - peeling to depth in which coarse aggregate extends to 1/4 inch below mortar

S3 - peeling to depth in which coarse aggregate extends more than 1/4 inch above sound mortar matrix

S4 - scaling which extends well into concrete

Faulting - differential vertical displacement of abutting slabs at joints and cracks

Mapping symbol.--a numeral written on the low-slab side of a joint or crack to indicate the depth of fault (1, 2, 3, etc. to indicate 1/10, 2/10, 3/10, etc. inches)

Pumping - the ejection of water-suspended material at joints, cracks and pavement edges by traffic loadings

Mapping symbol.--the letter "P," followed by a numeral identifying the severity rating

Severity rating.--

P1 - pumping, without faulting or cracking due to pumping

P2 - pumping accompanied by faulting resulting from pumping, but without cracking due to pumping

P3 - pumping accompanied by cracking resulting from pumping action

Bituminous Concrete Resurfacing Deficiencies

Reflection Crack - cracks in resurfacings above joints and cracks in old base

Mapping symbol.--single line on sketch sheet

Alligator Cracking - series of interlaced cracking forming small polygons

Mapping symbol.--"AC," with outline of area affected indicated on sketch sheet

Belt Cracking - parallel cracks, a few inches apart, with the bituminous concrete in a somewhat raised position between them, sometimes occurring over transverse expansion joints or wide-open cracks or contraction joints in base

Mapping symbol.--"BC," plus sketch of crack

Channeling (rutting) - wheelpath depressions

Mapping symbol.--covered by descriptive statement with estimate of average channel depth

Raveling - surface disintegration

Mapping symbol.--covered by descriptive statement including an account of severity

Pothole - bowl-shaped hole

Mapping symbol.--"Pothole," plus marking of location on sketch sheet

TRAFFIC

Route U.S. 66 in Illinois has been for many years a major artery of intercity and interstate passenger vehicle and truck travel. Although differences occur in the traffic characteristics along the route, the volumes of both passenger car and truck traffic remain relatively high throughout the entire length. Average annual daily traffic volumes for the period 1936 through 1968, separated by principal vehicle types, have been charted in Figures 5 and 6. The data used in preparing Figure 5 are for a location typical of those where the volumes of total traffic and of commercial traffic are highest; the data for Figure 6 are for a location typical of those where volumes are lowest. The year 1936, with which the charts began, is the earliest for which traffic count data are available. It will be seen from Figures 5 and 6 that, as would be expected, the average daily volumes of both passenger cars and trucks have increased tremendously over the years following 1936.

When the Route U.S. 66 Condition Survey was undertaken in 1949, it was hoped that truck axle-weight data from the stations on Route U.S. 66 where annual weight surveys were instituted in 1936 would be useful in relating pavement defects to loadings. This hope was never realized. First efforts to array the axle-weight

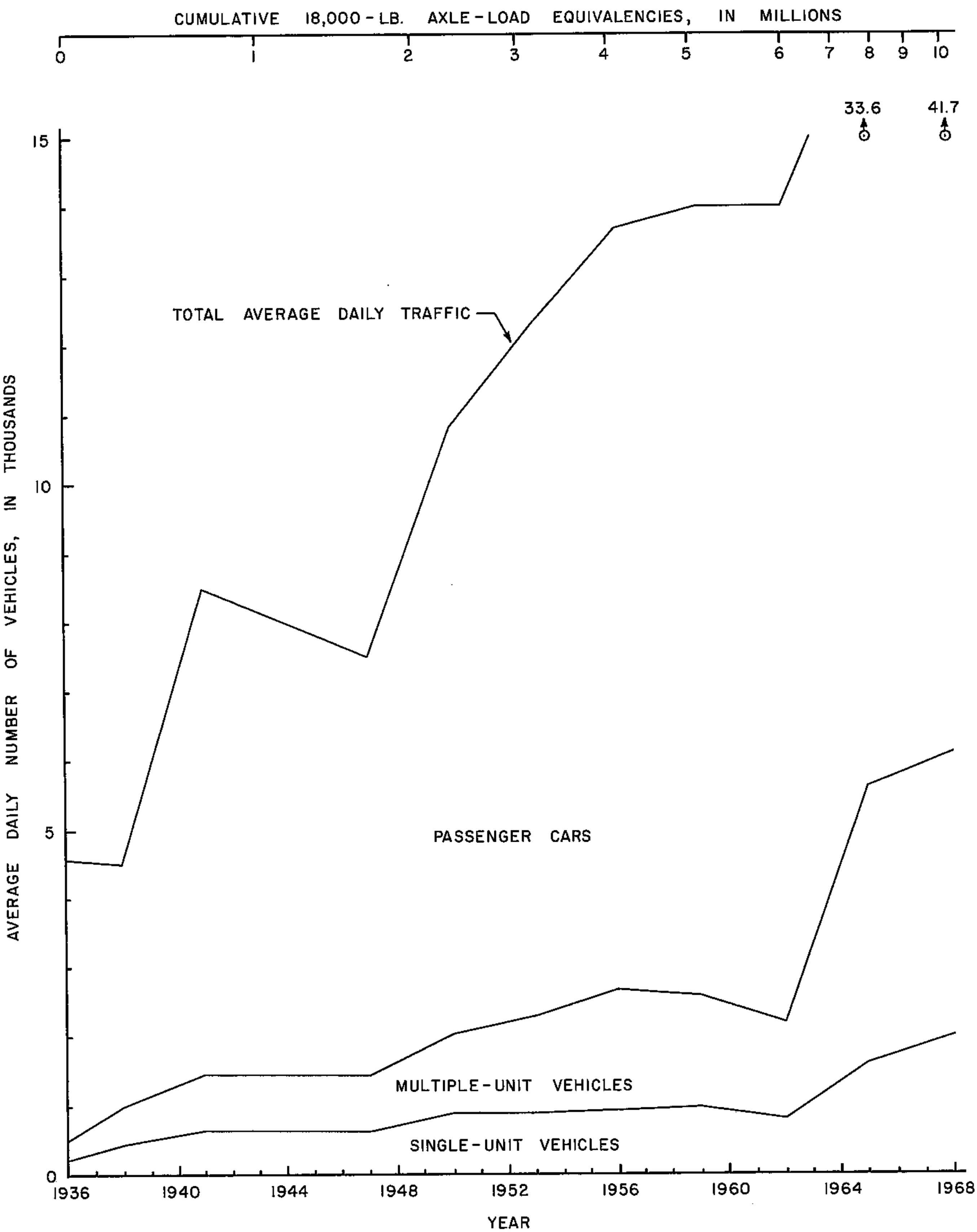


Figure 5. Traffic characteristics at typical urban location on Route U.S. 66 in Illinois

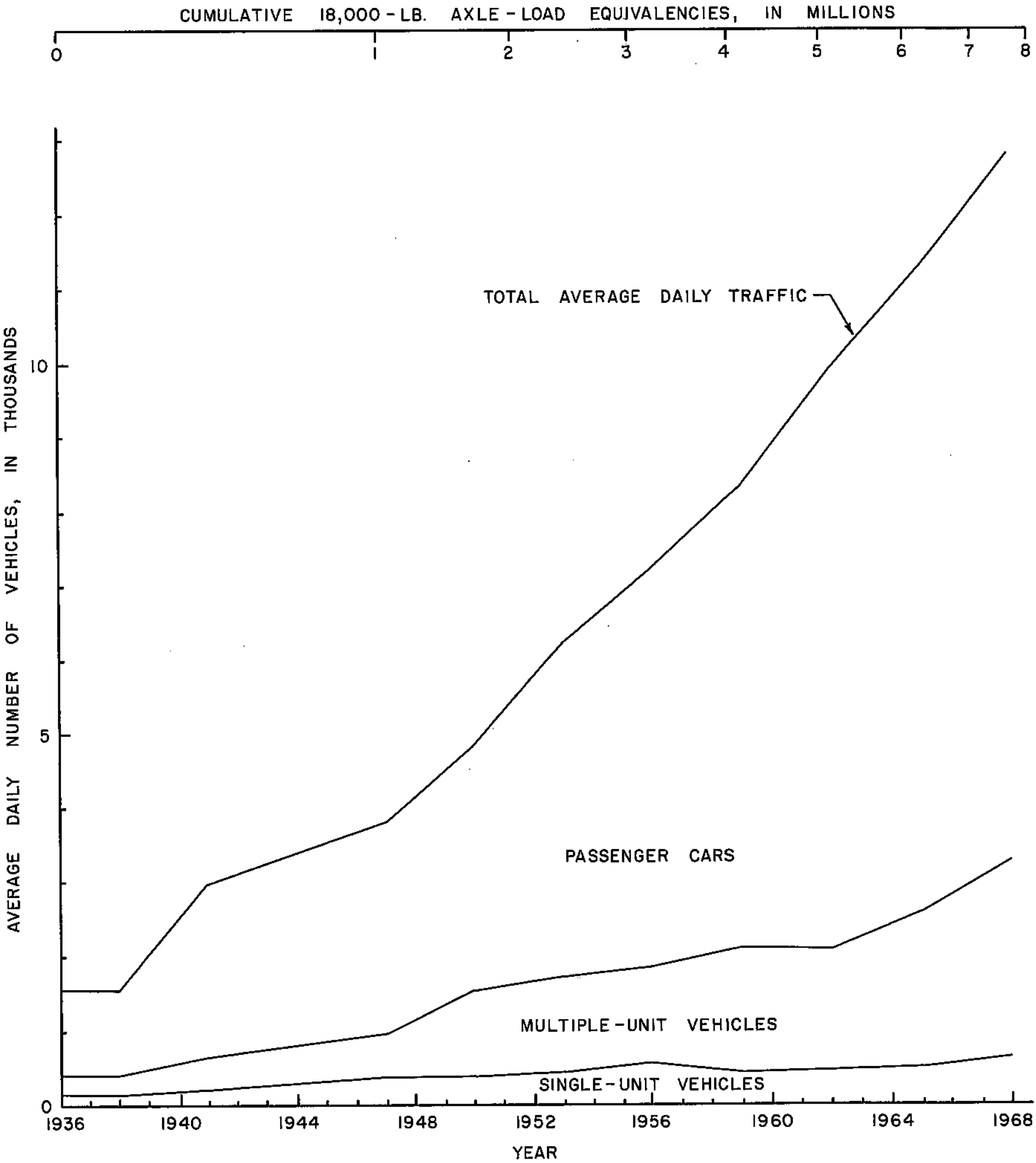


Figure 6. Traffic characteristics at typical rural location of Route U.S. 66 in Illinois

data from the individual stations showed an important lack of between-station and year-to-year stability and major unexplainable variations from Statewide trends. It seemed obvious that the data samplings were too small to provide adequate statistical stability. Consideration was given to the acquisition of greater quantities of data in later years, but the expense involved was never considered to be justified because of additional difficulties that were met in reducing the weight data to some form susceptible to analysis.

Analytical processes of the pavement serviceability-performance concept developed at the AASHO Road Test(1), that became available in 1962, offered the first opportunity for reducing mixed-traffic axle loadings to a common demoninator. While the application of this concept provided a means for analysis, it did not produce results with enough sensitivity to distinguish relationships between individual defects and traffic loadings, or to quantify the responses of design variables to traffic loadings. However, the use of field data from the Route U.S. 66 Condition Survey was of major importance in establishing modifying factors that permitted the use of the AASHO Road Test formulas in designing pavements to meet Illinois service conditions.

Concepts and procedures developed by the AASHO Road Test researchers and others to express mixed-traffic axle loadings in terms of equivalent numbers of a single-load axle are of assistance in demonstrating the general loading history of Route U.S. 66. The equivalencies are based on the load-effect relationship that was determined in the Road Test. Reference(2) reports on the development in Illinois of average load equivalencies in terms of 18,000-lb. axles for passenger vehicles,

(1) Carey, W. M., Jr., and Irick, P. E., The Pavement Serviceability-Performance Concept. Highway Research Board Bulletin 250 (1960).

(2) Chastain, W. E., Sr., et al., AASHO Road Test Results Applied to Pavement Design in Illinois. Highway Research Board Highway Research Record 90 (1965).

single-unit trucks, and multiple-unit trucks through the application of Statewide loadometer and classification count data. For these three classes of vehicles the average 18,000-lb. axle equivalencies have been determined to be 0.004, 0.117, and 0.947 respectively for portland cement concrete pavements in recent years. While minor variations in these averages occur from year to year, and while lower equivalencies undoubtedly would be more appropriate for the earlier years under consideration, the application of these equivalencies is sufficiently accurate to afford a general insight into the loading history of Route U.S. 66.

Making use of the foregoing factors, and assuming that the volume and character of the traffic is about the same in each direction as is usually the case in Illinois, the number of equivalent 18,000-lb. axles was computed for each year of the period 1936-1968, and the cumulative equivalencies in millions of 18,000-lb. single axles plotted across the tops of Figures 5 and 6. The increased rates of accumulation of the 18,000-lb. equivalencies is obvious in the Figures.

PERFORMANCE SUMMARY

Under the original plan for the project, quantitative relationships were to be sought between the extent and severity of all pavement deficiencies and the variables likely to be causative.

Of special interest were the load-associated defects and the increases in the extent and severity of these defects in relation to cumulative traffic loadings. Unfortunately, the complexities of the interactions between variables, and inadequacies in the traffic data, prevented the establishment of the hoped-for relationships.

Efforts also were made during the study to establish associations between defects and such possible items of influence as design features, pavement materials, and granular subbase usage. While the existence of certain qualitative associations was readily observable in the survey data, no quantitative associations were established. Following is a discussion of the more significant relationships that were noted.

Defects most often seen in the portland cement concrete pavements were cracking, spalling at joints and cracks, faulting at joints and cracks, pumping and scaling. Of lesser consequence, except in a few instances, was D-cracking and associated raveling. The occurrence of load corner breaks was limited almost entirely to interior corners of the older pavements 7 inches or less in interior thickness. Even in these pavements they were not seen in great frequency.

The portland cement concrete pavements of Route U.S. 66 were found to be almost totally free of map-cracking (a series of connected cracks enclosing areas of 8 to 25 square inches).

Blowups were noted to be associated with all pavement designs, although with least frequency in connection with the distributed steel reinforced pavements having expansion joints at 50-ft and 100-ft intervals.

Spall became most severe at unedged transverse joints and at cracks, particularly at those that had opened sufficiently for slab faulting to have taken place. Distributed steel reinforcement, where used, was reasonably successful in holding cracks closed and spall-free.

No transverse joint design and arrangement observed during the survey was particularly effective in the retention of sealants.

Cracking (transverse, longitudinal, diagonal), although listed among observed defects, is of itself no problem. Transverse cracks are expected to form in slabs with distributed steel reinforcement and are of no concern as long as the reinforcement prevents them from opening. Cracks become of concern when they open sufficiently to allow the entrance of water and incompressibles, or when slab faulting or spall of the slab edges takes place. Transverse cracking of consequence occurred wherever distributed steel reinforcement was not used, except in connection with the 20-ft spacing design which was relatively free of unfavorable intermediate cracking but not without other serious defects. A variety of longitudinal or meandering crack that begins at transverse joints and cracks and which seems to be the result of a tearing action brought about by a stress concentration during periods of slab expansion after incompressibles have infiltrated at the pavement edges, was much in evidence in those pavements not provided with expansion space. While fairly abundant, these cracks were rarely seen to be accompanied by more serious deficiencies.

No pavement design feature or group of features showing striking superiority in comparison with those of other pavements were observed during the course of the survey. The poorest performance was recorded for the plain concrete pavements of World War II years with expansion joints at 120-ft intervals, intermediate contraction joints at 20-ft intervals, and no load-transfer devices. Intolerable faulting took place at these joints. Intermediate cracking was not a serious problem. Inferior performance was also received from the plain concrete pavements of the early 1930's with expansion joints at 90-ft intervals and intermediate contraction joints at 30-ft intervals. Although load-transfer devices were a part of the joint design, serious faulting eventually took place, especially at the expansion joints. Intermediate cracking, accompanied by severe faulting, was also a problem.

The use of subbases for the control of pumping was found to be a necessity under the traffic loading and subgrade soil conditions existing on Route U.S. 66[3].

(3) Chastain, W. E., Sr., and Burke, J. E., Performance of Concrete Pavements on Granular Subbase. Highway Research Board Bulletin 52 (1952).

During the latter years of the survey, the dense-graded granular subbases that were found to be almost totally effective in preventing pumping during the early years of the survey were seen to be inadequate for the increased intensity of loadings that had taken place.

Air entrainment, which was first used in the pavements of Route U.S. 66 in 1951, was found to be a necessity in the control of scaling under the modern-day usage of deicing agents. Although it has not prevented scaling entirely, it has held it within reasonable limits. Some of the earliest pavements, although constructed without air entrainment, have shown a remarkable resistance to scaling for some reason not entirely clear.

Certain coarse aggregates have seemed to be associated with early occurrences of D-cracking. Few of the pavements, however, have remained completely free of this condition throughout their service lives. No quantitative relationships were discovered, and nothing sufficiently definitive was found to document specification changes that might eliminate the poorer performing aggregates.

Deficiencies found most frequently in the bituminous concrete resurfacings were reflection cracks and belt cracks. Some of the early mixes showed excessive channeling and occasional shoving, but those placed in 1953 and subsequent years following a mixture design change that established the minimum Marshall stability at 1500 lbs. have shown good resistance to channeling. Alligator cracking and potholing have not been serious problems except in isolated instances. In the instances where these defects have been severe, potholing has almost always taken place when alligator cracking has reached an advanced stage, and the conditions have almost always been associated with deterioration of the base concrete. Raveling was rarely noted during the condition survey.

AUXILIARY STUDIES

Two auxiliary studies, one concerned with paved shoulders and the other with extra-thick bituminous concrete overlays, were added to the Route U.S. 66 Condition Survey in the course of the investigation.

Paved Shoulders

During the routine surveys of the condition of the pavements on Route U.S. 66, qualitative descriptions of the conditions of the shoulders were recorded on the survey sheets. No pavement defects obviously attributable to inferior shoulder quality were ever detected.

In the early stages of the Route U.S. 66 Condition Survey, shoulder areas were commonly of earth with turf cover. As the study continued, more usage was being made of granular materials to improve stability, and during the final years of the study, paved shoulders came into use.

When Interstate 55 was constructed in 1963 bypassing Springfield to carry the through traffic formerly carried by Route U.S. 66, several experimental types of paved shoulder were installed. Included were sections of cement-aggregate-mixture (CAM) and pozzolan-aggregate-mixture (PAM) surfaced with asphalt and chips, and bituminous-aggregate-mixture (BAM).

The CAM and PAM shoulders deteriorated rapidly and were partially removed and surfaced with bituminous concrete in 1969. The deterioration process suggested a lack of resistance to brine accumulations resulting from deicing activity. The BAM shoulders have continued to serve adequately.

During the winter of 1964-65, severe problems developed in the newly constructed paved shoulders of the Stevenson Expressway (I-55) which had replaced older Route U.S. 66 immediately southwest of Chicago. With the advent of freezing weather, extreme upward displacement was accompanied by some lateral displacement, the frequent occurrence of longitudinal cracks about a foot from the pavement edge, and a considerable amount of random cracking between the longitudinal cracks and the interface of the pavement and shoulder. CAM, PAM, and BAM shoulder bases were each used on one or more of the construction sections involved. The CAM and PAM shoulder sections on the Stevenson Expressway differed from those near Springfield in that a bituminous concrete surfacing was used instead of a bituminous surface treatment.

Except for slight displacements, the deficiencies were confined to locations where CAM and PAM shoulders had been used.

Cores taken from the shoulders showed considerable disintegration of the CAM and PAM mixes that appeared to be attributable to exposure to salt brine.

Details of the study of the Stevenson Expressway shoulders have been reported previously[4]. The following major conclusions were reported:

"The displacement and attendant distress suffered by the paved shoulders of the Stevenson Expressway appear to have originated through the exposure of frost-susceptible and expansive material to excessive amounts of surface water. Several factors seem to have acted either in combination or separately to aggravate the condition, among them being:

(1) An embankment soil especially susceptible to frost expansion when exposed to large quantities of water; also one capable of expansion when exposed to moisture.
(2) A subbase material somewhat capable of frost expansion when exposed to water, but also capable of serving as a source of free water to be drawn upon by contiguous frost-susceptible materials.
(3) Base materials lacking durability when exposed to freeze-thaw cycles in the presence of water or brine."

The following recommendations were contained in the report:

"New Construction -

(1) Mixtures substantially more resistant to freezing and thawing deterioration in the presence of water and brine than the cement-aggregate and

(4) Paved Shoulder Problem - Stevenson Expressway. Illinois Division of Highways Research and Development Report 19 (1967).

pozzolan-aggregate mixtures of the Stevenson Expressway should be selected for use in shoulder bases.

(2) Structural design should be revised to provide for a substantially more positive means for removal of surface water and brine entering the structure; or to provide a substantially more positive means of sealing against the entrance of surface water and brine, or both.

"Existing Construction -

(1) Steps should be taken to improve drainage of existing aggregate subbase.
(2) The longitudinal separation between pavement and shoulder, shoulder cracks, and pavement joints should be sealed against the entrance of surface water and brine by the most positive means at hand."

Because the investigation of the Stevenson Expressway shoulders was undertaken after the problem was evident, details regarding many of the conditions that prevailed prior to failure could only be conjectured upon. Information from this study was used subsequently in establishing a controlled experiment at another location (Interstate 80) identified as IHR-404, Experimental Paved Shoulders on Frost Susceptible Soils.

Thick Bituminous Concrete Overlay

In the fall of 1964 two short sections of extra-thickness bituminous concrete overlay and a short control section of the three-inch thickness ordinarily used in Illinois were applied over an existing old portland cement concrete pavement of Route U.S. 66 near Litchfield in Montgomery County. The following are some details on the experimental project:

Test Section	Length	Layer Thickness: Binder	Layer Thickness: Surface	Total Thickness (in.)
Control	400 ft	1 at 1 1/2 in.	1 at 1 1/2 in.	3
Intermediate	800 ft	3 at 1 1/2 in.	1 at 1 1/2 in.	6
Thick	800 ft	2 at 1 1/2 in.; 2 at 1 3/4 in.	1 at 1 1/2 in.	8

The mixtures in all instances complied with the Illinois specifications for fine dense-graded bituminous concrete, subclass I-11.

After approximately six years of service, a field survey has shown:

(1) numerous reflection cracks are present in the 3-inch overlay

(2) few reflection cracks are present in the 6-inch overlay

(3) no reflection cracks have appeared in the 8-inch overlay

None of the sections have shown significant rutting. The 3-inch overlay has shown a significant increase in roughness during the six years following construction; the two thicker overlays have not.

Some surface raveling believed to have resulted from the use of a mixture that was too lean and from the disadvantages of cool-weather construction is present in all three test sections. In that the most severe raveling has been seen to be associated with reflection cracks, the severity of raveling is indirectly related to overlay thickness.

DISCUSSION OF SURVEY TECHNIQUES

The Route U.S. 66 Condition Survey was a detailed survey in which all observable conditions were plotted to scale on strip maps. Surveys of this type were not new at the time this survey was undertaken in 1949. In fact, most of the techniques adopted for use in the Route U.S. 66 Condition Survey had been applied earlier by others. Surveys in which the Portland Cement Association had taken part, and which were usually reported in Highway Research Board literature, were an important source of the information used in this survey.

Final proof of the worth of any design feature or material incorporated in highway construction lies in its service under actual field conditions. The condition survey has been an important tool of pavement designers and materials engineers in evaluating the serviceability of their products[5].

(5) Carey, W. N., Jr., The Need for Making Condition Surveys. Highway Research Board Highway Research Record 40 (1963)

The Route U.S. 66 Condition Survey was a load-condition survey in which the principal effort was directed toward finding and documenting a relationship that most highway engineers were convinced existed between pavement condition and the volume and weight of traffic loadings. Previous similar attempts had not been even moderately successful. Yet, the great need to furnish legislators with concrete evidence with which to face the strong pressures to which they were being subjected to raise legal weight limits, or even to eliminate them altogether, was sufficient to encourage further attempts.

The Route U.S. 66 Condition Survey was innovative in some respects. The repetitive survey concept seeking to establish a condition or performance history that hopefully would furnish sueful information that previous single surveys had failed to produce was new, at least in the scope of its application. In addition, the registering of both nontraffic-related defects as well as traffic-related defects to aid in isolating the effects of those chargeable to heavy loadings was untried.

The Route U.S. 66 Condition Survey, while contributing significantly to highway engineering in a number of ways, served no better than previous surveys in providing the sought-after load-condition relationship. This was not accomplished until the $27 million AASHO Road Test with its controlled traffic loadings became a realization.

Although it ultimately proved not to be of great consequence because of the difficulties of processing mixed traffic data, the Route U.S. 66 Condition Survey shared with other condition surveys the problem of inadequate axle-load data. In the beginning, the intention was to make use of loadometer data from two existing loadometer survey stations along the route. Examination of the data that had been obtained during prior years, and which were being obtained during the years of the survey, showed erratic trends that could lead only to the conclusion that the sample sizes were much too small to provide usable information when the results obtained at the survey stations were treated individually. The loadometer surveys usually were conducted over one to three eight-hour periods once each year. Only about a third of the trucks passing the stations during the weigh periods were weighed.

While the lack of statistical stability in the mixed-load traffic data was soon recognized, the difficulties of handling any kind of mixed-load data also became apparent. Without a reasonably satisfactory means for manipulating the data for analysis, the cost and the number of people who would be diverted from other assignments for obtaining the mass of data needed for a better representation of true conditions could not be justified.

The engineer originally assigned to the Route U.S. 66 Condition Survey had a strong background of previous condition-survey experience and was allowed to devote full time to the study. This individual, with the assistance of a second engineer, conducted the first full survey over a two-year period and processed all data that were obtained. This provided a uniformity of field recording and interpretation of the field data that was not equaled in later years.

Once the initial condition was logged, the logging of the increases in the extent and severity of defects seemed at the time to be fairly routine, and the field work was assigned to engineers of lesser experience, and frequently to two or three parties of technicians under the supervision of an engineer. Data reduction, which also seemed routine, was also assigned to an engineer and a squad of technicians only superficially knowledgeable of pavement behavior.

During the long period of the survey, many different engineers and technicians were employed in the study. While in most instances each engineer in charge of the study trained his successor, a certain amount of essential continuity was lost, and during the latter years the problems of data interpretation became numerous. In the end, the data that were recorded through the years, because of its very mass, created a situation in which the cost of further reduction seemed unjustified on the basis of likely return on the investment.

This retrospective review of the difficulties experienced during the Route U.S. 66 Condition Survey leads to several suggestions regarding hazards to be guarded against when pavement condition surveys are undertaken. Many of these are now generally recognized from experiences reported by others, but seem worth repeating when corroborated by what was perhaps one of the most ambitious surveys of the type ever undertaken.

(1) Condition surveys, such as the Route U.S. 66 Condition Survey, while seemingly routine in nature, present problems of interpretation for inexperienced engineers and technicians that can reduce or even negate their usefulness. When the question arises as to whether or not a detailed condition survey should be undertaken, the need for full-time and sometimes long-term assignment of an engineer with a relatively high level of pavement evaluation experience must be recognized. If such a person is not available for assignment, the risk of reduced return on the effort because of the assignment of an inexperienced man to the work needs to be considered.

(2) If a long-term survey is being planned, the problems of lack of continuity through changes in personnel must be recognized. Thorough and detailed advance planning will be needed to avoid the losses that can occur through changes in personnel.

(3) Careful advance planning must be made for data reduction and analysis. Field recording of nonpertinent data, and the recording of data in ways that office reduction becomes difficult or impossible, are to be avoided. Also to be avoided

is the gathering of masses of data with which available office forces are unable to cope because of the quantity involved. Means of data acquisition which can make use of modern computer data handling techniques should be explored. No field data should be obtained until the techniques for reduction and analysis have been firmly established.

(4) If the condition survey to be undertaken requires traffic data analysis, careful advance attention should be given to the representivity of existing data proposed for use, and to the sample-size requirements should new data be desired. The funding and personnel assignment for this effort can be great, and must be considered as part of the overall condition-survey effort.

IMPLEMENTATION

A significant part of the pavement condition data obtained during the course of the Route U.S. 66 Condition Survey was used by the Illinois Division of Highways to convert the formulas that explained the AASHO Road Test pavement performance under controlled traffic loadings into pavement design equations that reflect actual service experience in Illinois. The knowledge of the service behavior of the numerous design features and materials included in the pavements under observation, of the subbases that were used to control mud-pumping, and of paved shoulder experience, as observed in the Route U.S. 66 Condition Survey, has been and will continue to be helpful in the development of new designs and material usage. The condition survey experience gained through the years of this long-term study is also a very valuable background for the planning of future condition surveys.